Menlo Park Notebook #214 [N-81-02-20]

This notebook covers the period February-July 1881. The entries are by Charles L. Clarke and relate to dynamos. Included are notes, calculations, and drawings of the Porter-Allen central station dynamos, the South American portable dynamo, sizes E, F, and C dynamos, a steamboat dynamo, and a flywheel for an Armington-Sims steam engine dynamo. Thirteen loose pages found in the book contain additional notes, drawings, and calculations. The label on the front cover is marked "C. L. Clarke" and "Magnets." The book contains 278 numbered pages.

Blank pages not filmed: 72-99, 104-109, 224-253, 268-269, 278.

XE-172 N-81.02.20

Calculations for C. L. Clarke. 1
South American
Portable Dynamos. Feb. 20, 1881

Dynamo with 10¼" field diameter.

By the test of Jan. 29, 1881 the E.M.F. on lamps was 164 x.675 volts
= 110.7 volts. A

The E.M.F. on magnet-circuit was (30.95 ohms resis.) 240 volts.
Of this resis. 17.05 ohms were in the magnets, the remainder being in the regulating resistance.

The E.M.F. on the magnets was therefore 132.2 volts.

and with 11 magnets in series the fall on each was

12 volts.

Which corresponds to a deflection on the high resistance galvanometer in this case of 17°8.

The deflection of 164° corresponds to an average speed of 1203 revs. per minute and at 965 revs. the deflection would be

131°6

This with 17°8 on the magnet corresponds closely with experimental curves determined Dec. 10 1881.

Each core has 690 turns in 3 layers of No. 10 copper wire and average ~~distance~~ diameter of 6.456 ~~feet~~ inches

Length of one turn

$6.456 \times 3.1416 = 20.28$ inches

Total length in both cores 27986.4 inches

$= 2332.2$ feet.

The resistance is

$\frac{10.64 \times 2332.2}{(130)^2} = 1.47$ ohms.

Above was not quite O. K. No. 10 B. & S. gauge is .1394 diam. but .130 diam.

With an assumed conductivity of 97.

The weight of the wire is $2332.2 \times .054353$

$= 126.76$ lbs. but given wire was .130 diam.

$= 119.3$ lbs.

If the armature were single wound instead of double the E.M.F. would have been 55.35 Volts.

Suppose

T = turns of wire
C = Current
E = E.M.F.
R = resistance

Then Efficiency = $C \times T$

and Energy = $C^2 \times R$

If wire is of half the Cross section but same weight $r = 4R$.

$t = 2T$

Efficiency = $c \times t$.

which assume to be the same as before

$\therefore \quad c \times t = C \times T$

but $t = 2T$

$$\therefore \quad c = \frac{C}{2}$$

Energy $c^2 \times r = \frac{C^2}{4} \times 4R$

$$= C^2 \times R .$$

The amount of energy in the two cases is therefore the same.

To produce however half the current C through four times the resistance R requires an E.M.F.

$$= 2E$$

Therefore with a given weight of copper and a constant efficiency and constant energy

$$\text{E.M.F.} \propto T$$

$$C \propto \frac{1}{T}$$

$$R \propto T^2 .$$

Also

Cross-section of wire $\propto \frac{1}{T}$

Efficiency $\propto$ (diam. of core)$^{\frac{1}{2}}$,

Efficiency $\propto$ (length of core)$^{\frac{1}{2}}$.

The present dynamo gives 55 volts at the speed of 1203 revs. ~~at~~ near the saturation point which would not be wise to regulate automatically. A lower point on the curve of magnetism should be taken where the curve is approximately a straight line, say at the point where at 965 revs. the E.M.F. is 39.15 volts with ~~7.4~~ 6.75 volts in the magnet. At 1203 revs = 48.8 volts

If x is the product of the length by the diam. of core

$\sqrt{x} : 55 :: \sqrt{36 \times 6} : 45.8$

$\therefore x = 275$ appx.

If the core is still kept 6" diam. the length will be 46 inches.

If 6½" diam.
length 42½".

The size of cores will be 6½" × 42½".
but ½" will be added to the length to allow for fiber and iron washers.

The yoke will be 6½" deep by 7½ wide.

The field ~~coils retain their present dimensions width 9¼"~~ be 9½" wide.

Amount of copper 120 lbs.

On each core - 60 lbs.

The energy required to be developed in entire magnet circuit is

$$\frac{6.75^2}{1.47} \times 44.3 = 1373 \text{ ft-lbs.}$$

On the cores to separate the coils from the yokes and poles must be placed fiber rings.

Feb. 21, 1881
Clarke.

Suppose no resistance in the magnet-circuit other than the coils in the magnet itself the resistance required to give the energy of 1373 ft.-lb. on 55 volts will be

$\frac{55^2 \times 44.3}{1373} = 97.6$ ~~rebes~~ ohms.

or a current 563 rebes.

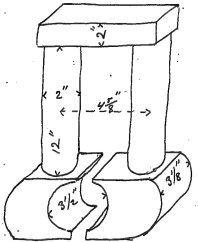
~~The small magnet intended for the regulator has a core 18" long by 3" diam. and this must be at all times saturated~~

See page 37 for continuation of resistance.

For regulator use a magnet 1/3 the size of the medium machines.

Core 12" long x 2" diam.

Yoke 2" x



Let the amount of copper be in proportion to that on the medium machines which have 120 lbs. The

amount for the regulator will be $\frac{120}{27}$ =

Armature Clarke.

The field will be 10¼" diam.

Clearance between field and armature bridging wire $\frac{3}{100}$".

Diam. of brass or German silver bridging wire $\frac{2}{100}$" (Number 25 B.W.G.)

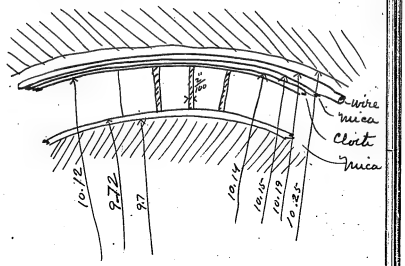
Mica under bridging wire $\frac{5}{1000}$" thick.

Cloth covering under mica $\frac{10}{1000}$" thick

Mica over armature and under copper rods $\frac{10}{1000}$" thick

Depth of copper rods on armature $\frac{2}{10}$".

Diam. of armature core $9\frac{7}{10}$".



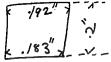
Diameters

The 78 divisions of the armature are on an outer ~~section~~ diam. of 10.12 and inside diameter of 9.72.

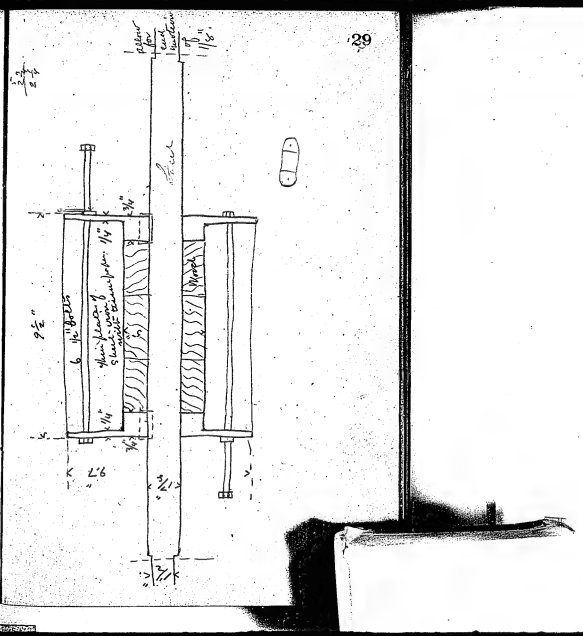
Middle of 1 division on outside diam. .212"

ditto inside .203"

With a separating insulation of $\frac{2}{100}$" the actual middle becomes .192" and .183".



See page 53 for Commutator blocks.


Aluminum Honeycomb Structure Beam 1¼"
6 ½" Bolts
9 7/8"
9 7/8"

5 1/4"
3/16
3/8
4 Rails
3/4"
3/8"
3/4"
1/4"
Straighten down 3/8" to match diameter

150 divisions

3/4"

37 to division in 150

74
75
76

73 blocks with 1" insulation

73

25

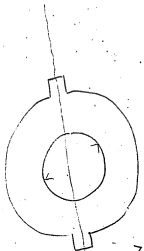
Vapo

37

3.1416

75 / 15.7080 (.2094
15.0 xx
708
675
330

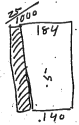
.2094
.0525
.1569



3.1416

75 / 12.5664 (.1675
7.5 xx
506
450
566
525
414

.1671
.0525
.1925



Commutator blocks

The ft. lbs. actually required to saturate the medium sized magnets is

$$\frac{20 \times .675}{1.47} \times 44.3 = 5492 \text{ ft. lbs.}$$

but with the magnet ½ inch larger in diam. and longer 7" greater and also considering the fact that the E.M.F. will be of the required intensity some distance down the curve from the saturation point (only 1373 ft. lbs. being actually required) we will assume 3500 ft. lbs. as required of which the half may be used up in regulating resistance but actually the effect will be by Counter E.M.F. of the regulating motor.

The necessary resistance will be

$$R = \frac{5^{\overline{5}-2} \times 44.3}{35.00} = 38 \text{ ohms}$$

If L is the length of conductor and D the diam. in thousandths of an inch

$$R = 38 = \frac{10.64 \times L}{D^2}$$

but weight is 120 lbs. and one mile-foot weighs .000003027

$$\therefore \quad D^2 \times L \times .000003027 = 120$$

$$L = \frac{120}{.000003027\, D^2}$$

$$\therefore \quad 38 = \frac{10.64 \times \frac{120}{.000003027 D^2}}{D^2}$$

from which

$$38 D^2 = 10.64 \times \frac{120}{.000003027 D^2}$$

$$\therefore .000115026 D^4 - .0003220738 D^2 = 120$$

$$\therefore D^4 - .28 D^2 = 1043240$$

$$D^4 - .28 D^2 + .0196 = 1043240.0196$$

$$D^2 - .14 = \pm 322.79$$

$\therefore \quad D^2 = 323.13$

$\quad or = 322.85$

$\therefore \quad D = 17.975$

$\quad or = 17.968$

Assume No. 26 B.W.G.

of $\frac{18}{1000}$" diam:

Suppose the weight in a rod 1ft long - 120 lbs.
Since a mile-foot weighs .00003027 there would be

$120 \div .000003027 = 39643211$ miles in the rod.

For a constant weight of metal
Resis. $\propto$ (length)^2.

Resis. of this rod is $\frac{1064}{3964321100}$ ohms

but since the resistance is to be 38 ohms the length L

$$L = \left(38 \times \frac{3964321100}{1064}\right)^{\frac{1}{2}}$$

$$\therefore \quad L = (141582896)^{\frac{1}{2}} = 11898 \text{ feet}$$

The mils in cable vary inversely as L, therefore the

Circular Mils = $\frac{39643211}{11898}$.

= 3332.48

Diam. = $(3332.48)^{\frac{1}{2}} = \frac{57.7}{1000}$".

By taking No. 17, B.W.G = $\frac{58}{1000}$

the ~~resistance~~ number of feet will be 11784.5 feet.

The Resistance

$R = \frac{10.64 \times 11784.5}{(58)^2} =$ 37 1/4 ohms.

See p. 51.

Since on 37 1/4 ohms 1373 ft. lbs. are required at the dynamo to be developed, the weight of copper not having been altered, the E.M.F. necessary is $E = \left(\frac{1373 \times 37\frac{1}{4}}{44.3}\right)^{\frac{1}{2}} =$ 34 volts.

55 volts being all required of the machine at this point the ~~remaining~~ total resistance for regulation will be $\frac{55 \times 37\frac{1}{4}}{34} = 60\frac{1}{4}$ ohms

The regulating resistance outside the magnets will be $60\frac{1}{4} - 37\frac{1}{4} = 23$ ohms.

To have a margin and for making the lights less brilliant introduce 22 ohms extra making in all 45 ohms in boxes.

If made of German silver wire of $\frac{32}{1000}$" diam. No. 21 B.W.G. the necessary length will be

$$L = \frac{45 \times \overline{32}^2}{10.64} \times \frac{1}{7}.$$

$$= 6.20 \text{ feet.}$$

Sabbidge 49.

If we have 5 boxes of 1 ohm each the length of wire on each wire be 15.5 feet and on each of the 5 ohm boxes (of which there wire be 8) 77.5 feet.

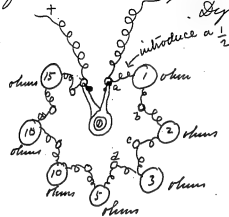
If boxes are 3" square there will be 1 for. for a turn and 8 threads to the inch the height of boxes will be 9.7 inches. This will enable them to be placed in a box 1ft high.

The 5 coils of 1 ohm each can be wound in 1 of the boxes for 5 ohm coils.

The box would be a cube of 1 ft Must have holes for air circulation.

Clarke.

Resistance box for regulating field for South American Dynamos.



The total length of wire will be 620 ft. or 13 ft 9½" to the ohm.

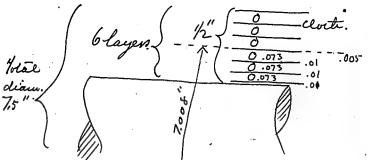
a, b, c, d, etc must be so close that the switch will span the space and circuit never be broken.

See page 55

If 17 B.W.G. is used on the magnets, the diameter of .058" will be increased by the double cotton insulation to ~~.065~~ .073".

There are 42" of available length on the cores.

This gives 575 turns to a layer



With six layers the diameter (mean) will be $6.5 - .438 = 6 \times .073$
$.07 = 7 \times .01$
7.008 inches

The total length will be 12680 feet and the

resistance

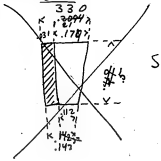
$$R = \frac{10.64 \times 1265.0}{35^2}$$

$$= 40 \text{ ohms.}$$

Commutator 5" diam.

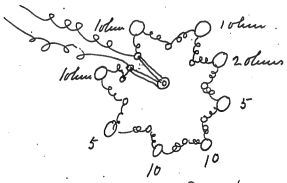
$$\frac{3.1416}{5} = .2094$$

75) 16.7080 (.2094
150 x x x
708
675
330

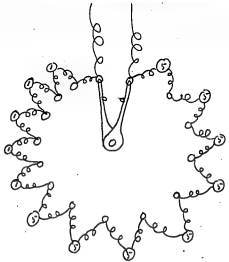


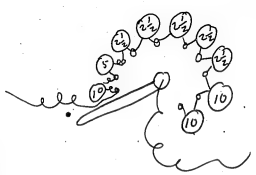
See page 35.

This arrangement controls each resistance. As also does an ordinary plug.



See page 57.





~~For a 20 ohm coil of No. 30 American gauge ($\frac{1}{100}$") are required 196 feet.~~

2 Bunsen cells of $\frac{3}{10}$ ohm or 3 ohm magnet- give strong suction. This is 4 volts or $\frac{33}{10}$ ohms or $\frac{30}{33}$ of 4 volts = 3.7 volts on magnet. Total resis. 22 ohms of which 2 ohms are in magnet of No. 26 copper wire American gauge = 49 feet. .01599 diam.

Resistance of the South American machine (55-Volts).

The cross section is $\left(\frac{.192+.183}{2}\right).2 = .0375$ sq. in.

Since 1 mil. (circular) is .0000007854 sq. in.

The no. of circular mils will be $\frac{.0375}{.0000007854} = 48001$ cir. mils.

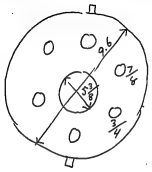
The mean length of the rods is $\frac{(14.158+14.197)}{2} = 14.178$ inches

$= 1.1815$ ft.

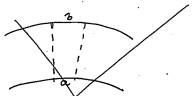
The resistance of this part of the circuit will be

$$R = \frac{10.64 \times 150 \times 1.1815}{4 \times 48001}$$

$= .009821$ ohms.



Mean ~~radius~~ diam of copper plates 7.4875"



If any element of a ring is taken and at a we have for unit length a unit length weight w of metal $\propto l \propto r$

and mean length or their diam. = 23.5"

Depth of rings 2".11.25

thickness .028.

Approximately the cross section is 2.1125 X .028 = .059

for 18.5 inches

~~2.1125~~

1.2375 X .028 = .03465

for 1.775 inches

1.3625 X .028 = .0383

for 2.25 inches

For the diminishing of the cross section by the holes increase length 4 25 inches = 2.083 ft.

In .059 sq. in. there will be

$$\frac{.059}{.0000078854} = 75121 \text{ cir mils.}$$

$$R = \frac{10.64 \times \frac{75150}{75121} \times 2.083}{8 \times 75121}$$

$$= .0155 \text{ ohms.}$$

The total resistance will be see pages 61 & 65

.00982 + .0153

= .0253 ohms.

The $\frac{14}{100}$ machine will run 50 A.16 lamps and that is about the limit on account of heat. 115 ohms each.

$\frac{115}{50}$ = 2.3 ohms.

110 volts.

$\frac{110^2}{2.3} \times 44.3 =$ 233057 ft-lbs (7.06 H.P.)

The amount developed, as heat, in the machines will be $\frac{14}{230}$ of 233057 = 14186 ft-lbs.

Total 233057 + 14186 = 247243 (7.5 H.P.)

Ratio of external to internal 14.4 to 1.

The South American machine has a resis. of .0253 ohms. The B. 16 light has the same radiating surface as the A. 16 and with $\frac{1}{2}$ the E.M.F. (or 55 volts) and same length as B. 8 it has the same foot-lbs. of energy – Therefore the energy will be (page 67) for 50 lamps 23.3057 ft. lb. The resis. external is $\frac{115}{4 \times 50}$ = .575 ohms and internal is .0253 The heat developed pr armature will be $\frac{253}{5750}$ of 23305 = 1025.4 ft. lbs. Ratio of external to internal 22.7 to 1.

In order that as much heat may be developed in the armature in the last case as with the $\frac{14}{100}$ dynamo with A16 lamps we must leave (the ft. lb. for each lamp being $\frac{233057}{50} = 4661$ ft. lb.)

If x = number of lamps the external resi. is

$$\frac{\frac{115}{4x}}{\frac{.0125-3}{\frac{115}{4x}}} \text{ of } 4661x = 14186 \text{ ft lb.}$$

$$.1012 \times 4661x = 115 \times 14186$$

$$471.6932x^2 = 1631390$$

$$x^2 = 3459$$

$$x = 59 \text{ lamps.}$$

Dynamo B.

The size of dynamo A is larger than what is absolutely necessary for the given E.M.F. but it was increased so as to make automatic regulation better by being on the straight portion of the curve of magnetization.

At ~~1200~~ 961 revo. the deflection is 131.3 which would give at 1200 revo. 163° def. = 11.06 Volts. This corresponds to a def. on the magnet of 140° = 9.45 Volts. This is a good point on the curve for economy and regulation. The energy required on the magnet would be .2691 ft. lbs.

The field of the dynamos in experiment have a width of 9 1/4" which we will reduce to 9" or by 2.7% but this can be more than made up in decreasing the diam. of the iron of the core.

The rim of the armature has been 9.7 outside radius and inside and area as expressed by $(9.7)^2-(\frac{5}{8})^2=69.09$ But inside radius can be decreased to at least $3\frac{3}{8}$" then $(9.7)^2-(3\frac{3}{8})^2=82.7$ an increase of 5%, this more than counteracting the effect of decreased width of poles.

Also see 265 page 111

Central Station Dynamo.

March 29, 1881.

In the Porter-Allen dynamo, by increasing the commutation from 69 to 75, the speed may be reduced to

75 : 69 :: 600 : 552

No. revo. with 75 comm. = 552

By increasing the length of armature from 28" to 33¾" the speed may be reduced to 33.75 : 28 :: 552 : 458

No. revo = 458

Arm. 33¾" long

To reduce the revolutions from 45-8 to 35-0 the diam. must be increased by a ratio of

1 : x :: 350 : 45-8

Ratio of increase of diam. of armature = 1 : 1.30857

Actual necessary diameter

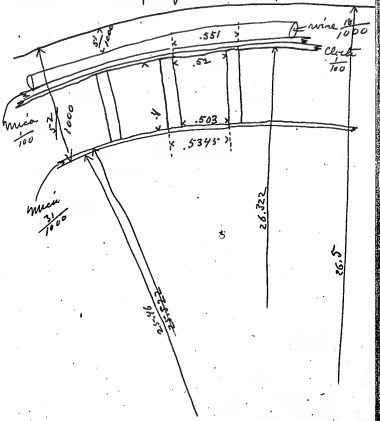
1.30857 × 19.46

= 25.46".

If the space remains the same as before $\frac{5-2}{100}$" the diam. of field will be

= 26.5".

See page 129 for correct skeleton



The diam. on the mica insulation is 25."522 and circumference 80."1799152 and with 150 bars the space for each on this diam. will be .53455 inches.

With $\frac{1}{32}$" insulation the bottom width of rod will be .503"

Assume the rods as .40 deep, the diam. on outside ~~diam~~ of armature rods is 26.322 and circumference 82.693 and with 150 bars the space for each on this diam. will be .55513

With $\frac{1}{32}$" insulation the top width of rod will be .52

In the Potter-Allen Dynamo
the following are dimensions
of armature rods

And number of commutator
blades 69. length 28"

In Central Station Plant

75 commutators, length $33\frac{3}{4}$".
+ $7\frac{7}{16}$" with plates .065 thick
and insulation .02 thick.

Resis. $= \frac{10.64 \times 25 - 6.25}{260441}$

$= .01047$

Entire resis. of armature
$= .005235$ ohms.

O. K.

By reducing the no. of commutator to 73. the diam. should be increased from 25.46 to

73 : 75 :: 25.46 : 26.16

= 26.16

Which we will increase to 26.46

Circumference = 83.126736

With 146 armature bars the space for each at bottom

$\frac{1}{2}$ = .56936 and

with $\frac{1}{32}$ insulation,

actual bottom width

= .538

Outer circumference of armature rods with

27,322 drain.

= 85.8347952

Top space for each of 146 rods = .5879

With $\frac{1}{32}$" insulation

= .557

Area = .219 sq. in.

= 278839 c. mils.

Length of each rod 41 inches and total of 146 73

~~= 498.83 feet~~

= 249.415 "

$$\text{Resis} = \frac{10.64 \times 249.415}{278839}$$

= .00952

Total resis = .00476 ohms.

$\frac{600}{3}$ $\frac{350 \times 26}{600 \times 20}$

With 120 Horse power outside

$\frac{\overline{110}^2}{R} \times 44.3 = 3960000$

$R = .13536$ ohms.

Ratio of armature rods to

External total $\frac{.00476}{.13536} = \frac{1}{29}$

~~Ratio of armature rods to~~

~~external~~

~~$\frac{.00476}{.1306} = \frac{10}{274}$~~

In the $\frac{14}{100}$ dia machine the loss of energy with 50 lights will be as follows—

Resis. $\frac{50}{115}$ ohms

with 110 volts drop gives

$\frac{50}{115} : 110 :: \frac{x}{100} : = 10.12$ volts.

$\frac{10.12^2}{14} \times 44.3 = 82400$ ft. lbs.

Armature has the two ends and face to radiate from

$= 10\frac{1}{4}$ diam. $9\frac{1}{4}$ long th

$= 463$ sq. in.

$\frac{32400}{450} = 72$ ft. lbs. per sq. in. radiate.

Large armature rods.

See page 123, Circumference

$= 85.835$

Surface $= \times 41 = 3671.9$ sq. in

$\frac{136552}{3520} = 31$ ft. lbs. per sq. in. radiate.

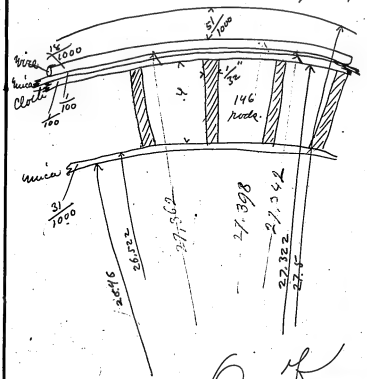
March 30. 1881.

Connect Central Station

Dynamo.

Copper wire 68/1000

Insulating paper 20/1000



O. K

In the Porter-Allen dynamo with a ratio of internal resis. to external of 1 to 22 the face of E.M.F. in armature is 5 volts, making a total necessary of 115 volts. To obtain this at 600 rev. the point on the magnetization curve is economical.

The current required to effect this is $\frac{75^{\circ} \times 675}{23} =$

2.201 webers.

~~For a magnetic strength of~~
~~displacement of~~
The no. of turns on a magnet is 3720 and produce 2.201 X 3720
= 8187.72

23) 116 (5

With new helices. 4 1/2 6" instead of 3 1/2 6" as in Porter-Allen Dynamo the no of turns will increase in the ratio of

42" 6-5-4"

= 4783 turns

Assume that 100 volts will give the current of 2.201 webers. we must have a resistance of

100 ÷ 2.201 = 45.5 ohms.

Euit

To get the same current through 4783 turns of 45.5 ohms as through 3720 turns of 23 ohms requires a ratio in diam of copper

$$R = \frac{10.64 \times 4783}{x^2} = \cancel{48.5}\ 15^{\circ}$$

$$r = \frac{10.64 \times 3720}{(109)^2} = 23.$$

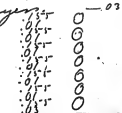
$$\frac{\cancel{(48.5)}\ 15\ x^2}{4783} = \frac{23 \times (109)^2}{3720}$$

$x = 154$

The wire nearest to this is No. 8 = $\frac{165}{1000}$ and with insulation would be $\frac{19}{100}$ ~~With cores~~ too large.

With wire .130 and insulation .025 . total diam. = .155

4783 turns can be got in 4'6" cores with 7 layers



Suppose 8" cores

8.170
1
9.170

Omit

Total diam
$8 + (1.17)2 + (.03)2$
$= 10.4$ inches
but distance between
centers is $11\frac{1}{4}$".
Therefore, .85" clearance
between.

Mean diam of copper
wire is 9.17
Circumference 28.808
Total length =
$4783 \times 3 \times 28.808$
$= 413365.992$
$= 34447.166$ feet
Resis $= \frac{10.64 \times 34447.166}{180^2}$
$= 21.7$ ohms.

Quit.

With wire .148 and insulation .025" Total drain = .173

.03

0 .173
.01
0 .173
.01
0 .173
.01
0 .173
.01
0 .173
.01
0 .173
.01
0 .173
.03

8 1.301
1.301 2
9.301 2.602
.06
8. 10.662

O. K.

Drain = 10.662 "

Clearance = 11.25 - 10.662

= .588 "

Mean drain of copper wire = 9.30 "

Circumference = 29.22

Total length of wire

= 4370 × 3 × 29.22

= 383074.2"

= 31922.85 feet

Resist = $\frac{10.64 \times 31922.85}{148^2}$

= 15.6 ohms.

O. K. Seepage 143

Length of Armature 33 3/4"

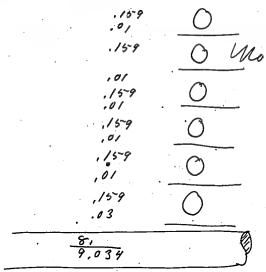
Diam. of " 26.46

" " poles 27.322

Length of cores 4ft 7"

Diam of cores 8"

.159
.01
.159 — No. 10
.01
.159
.01
.159
.01
.159
.01
.159
.03
8.
9.034



Mean diam 9.034
3.1416
54204
9034
36136
9034
27102
28.384 ÷ 144

139/54.000(340
417
830

340 turns in a layer
2040
4080 turns in a magnet
= 9649.2 feet
and for three magnets
28948
28948 × .054353 = 1578 lbs.

Thickness of discs .065
" " insulation .020

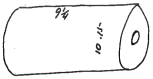
See page 141 for lengths of wire = 31922.85 feet.

31922.85 × .066303
= 2117 lbs.

For the Buckeye
With 6 layers of No. 10 wire the no. turns in each magnet = 2040
Total length = 28950 feet
Resi = 16.7 ohms.
Weight
28050 × .054353 = 1530 lbs.

Steam boat dynamos.

The medium sized machine having a resistance of $\frac{14}{100}$ ohms has an armature of the dimensions outside of wire



Circumference = 31.857"
Radiating surface of face = 295 sq. in.

With 50 lamps of 115 ohms resis. the joint-resis. is $\frac{115}{50}$ = 2.3 ohms and internal resis. is .14 ohms. With 110 volts outside the drop inside

will be 6.7 watts.

Total energy lost in armature

$\frac{6.7^2}{.14} \times 44.3 = 14205$ ft. lbs.

Of this energy half is radiated as heat from the cylindrical surface

7102.5 ft. lbs. from 295 sq. in. of surface

= 24.1 ft. lbs. from each square inch.

The resistance on the face will be $\frac{7}{100}$ ohm, and of each end $\frac{3\frac{1}{2}}{100}$ ohm, with a radiating surface but $\frac{1}{4}$ th the cyl. surface.

In South American dynamo
The length of each rod is
$\frac{14.158+14.197}{2} = 14.178"$

The no. of commutator is
75 and the resistance of
one side is

$$R = \frac{10.64 \times \frac{14.178}{12} \times 75}{\frac{(.192+.183).2}{2}} \quad \text{See page 27}$$
$$.0000007854$$

$= .019747$ ohm.

and for both sides a total
resistance of
$= .0098735$ ohms.

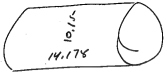
With x lamps (B. 16) with
$\frac{115}{4x}$ ohms resis. the total
outside resis. will be
$\frac{115}{4x}$.

The B.16 lamps require 55 volts - For the regular A.16 requires a certain amount of energy expressed by $\frac{V^2}{R}$ and in the case of the B.16 by making E.M.F. = $\frac{V}{2}$ and Resis. = $\frac{R}{4}$ we have

$$\frac{\left(\frac{V}{2}\right)^2}{\frac{R}{4}} = \frac{V^2}{R} = \text{same}$$

energy as before.

The annulatire is



Circum = 31.887

Radiating surface 452.1 sq. in.

The outside resistance being $\frac{11}{4}\Omega$ on 55 volts, the drop

in armature face will be

$$\frac{55 \times .0098735 \times 4x}{115}$$

and the energy developed will be

$$\frac{\left(\frac{55 \times .0098735 \times 4x}{115}\right)^2}{.0098735} \times 44.3$$

$$= \frac{1.601}{\cancel{1662.22}} x^2$$

To obtain the same radiation per unit surface as before namely 24.1 ft. lb. per sq. in. we have

$$24.1 \times 4552.1 = \frac{1.601}{\cancel{1662.22}} x^2$$

$$x^2 = 6805$$

$$x = 83 \text{ lamps.}$$

Therefore in respect to radiating surface the machine is ample

With 50 lamps of $\frac{115}{4}$ ohms each the face is 55 volts on $\frac{115}{200}$ ohms, suppose also 4 per cent. of this face as conductors = 2.2 volts, then assume the resistance of the end discs as equal to that of the armature face, which will be ample to make up for increased resistance due to connections, the total armature resistance will be

.0098735 × 2

= .0197470 ohms.

And the face will be

$\frac{55 \times .01975 \times 200}{115}$ = 1.9 ~~Ohms~~ Volts.

The total required E.M.F. will be 59.1 and as contingency for polarizing make it 60 volts.

By the curve which is taken as a basis of calculation the product of the current by the no. of turns should be 4700 and the value of 1 ft. of cutting wire at 1000 ft. per minute should equal .24 volts.

The face of magnet being 9.5" and 75 commutators single wound, the entire length of cutting conductor is 59.375 feet

The diam of core of armature is 9.7 and let 1200 revs. be assume, which will give a cutting speed of 3047.35 feet per m.

59.375 X 3.04735 =

= 180.9364

Volts required

60 ÷ 180.9364

= .33161 volts per foot

at 1000 ft. per min. are

required.

To attain this the product

of the current by the turns

must be be increased in

like ratio

.24 : .33161 :: 4700 :

= 6494

In the case of the medium

machine from which the

experimental data were

determined the product

4700 was obtained on a

one 36" long and 5

obtain 6494 in like proportion we have

$$4700 : 6494 :: 36 :$$

$$= 50''$$

Omit.

To which add 1" for washers.

$$= 51''$$

$$= 4^{A}3''$$

Instead of increasing by length let the increase be by diameter also, the cores were 6" diam. We have therefore

$$\frac{6^2 \times 36 \times 6494}{4700} = 1792$$

and if 6.5" diam.

$$\frac{1792}{(6.5)^2} = 42.4$$

which increase to 43" for washers and make the available length

$$= 42''$$

Instead of 55 volts on magnet assume but 75%
= 41 volts

If R is magnet resis.

Current is $\frac{41}{R}$

And T = no. turns

$$\frac{41\,T}{R} = 6494$$

$$\frac{T}{R} = 158.4$$

Assume 40 ohms

Then

$T = 6336$

Wit No. 17 B. W. G. and double cotton 15 turns insulation the total diam. = .058 + .015
= .073

and turns in one layer
= 42" ÷ .073 = 575

575
12
6900

6336 ÷ 575
= 11 turns or
5.5 to each core

See page 51

With six layers and
taking account of the
insulation we have
1265-0 feet and resis.
of 40 ohms.
and weight
= .010183 × 1265-0
= 128.8 lb. of copper.
The product of the turns
by 41 and division by
40 ohm will give
6900 which is more
than required, but the
nearest by regular B.W. Gauge.

When but few lamps are
on the face right votes
may be considered as outsides

With 100 lamp machine
assume capacity for 125 lamps.
From page 153 the capacity
of 50 light machine is in
reality 83 lights.
and now this has to be in-
creased to 125 lamps.
The cross-section of arma-
ture wire showed increase
in like proportion

And its dimensions be
in the ratio of the square
roots. as $\sqrt{83} : \sqrt{125}$

9.11 : 11.18

1 : 1.23

From page 27 the dimensions of the rod for the 50 light machine will be

and this should be increased in ratio of 1.5 1.23

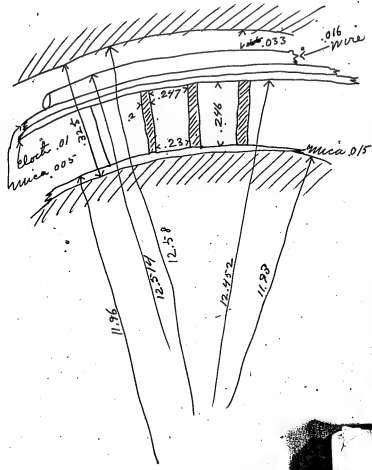
If the diam. 9.7 is increased in same ratio it becomes 11.93. Let the insulation under the rods be .015"

Depth of rods .2 X 1.23 = .246"

Cloth .01"

Mica .005"

Copper Discs $\frac{28}{1000}$"
Insulating paper $\frac{11}{1000}$"



The distance of field from armature core is

=,325

and at this distance 1 foot of cutting wire at 1000 ft. per minute = ,22 Volt | Showed be .2341 ~~ohms~~ but margin

and product of current by turns will be as determined by diagram = 5948

add 4 = 6100

With 125 lamps of $\frac{115}{4}$ ohms each, the total will be

$\frac{115}{500}$ = ,23 ohms.

At the same cutting speed as dynamo D the revolutions per minute will be

$$\frac{9.7 \times 1200}{11.93} = 975 \text{ revo.}$$

Cutting speed
= 3045.2 feet

Value of 1 foot at 1000 feet
= .22 volts

Value at 3045.2 ft. per m.

$3.045.2 \times .22$
$= .669944$

To give 60 volts it requires

$$\frac{60}{.669944} = 89.6 \text{ feet of}$$

cutting conductor.

With 75 commutators
this will give the required
length of field

$\frac{89.6 \times 12}{75}$ = 14½" approx.
slightly excessive.

Cutting wire 90.6 feet.

$\sqrt{(.247 \times .23)}$ .246 = .058671 sq. in.

Resistance = $\frac{90.6 \times 8.357}{58671}$

= .0129 ohms.

Resis. total
= .00645 ohms.

To the length of field (14.5")
must be added 4.678 for
extra length of rods to
the discs = 19.178"

This increases resistance

in the ratio of

14.5 : 19.178 :: .0064 :

Resis. = .00853

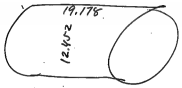
From page 175 joint resis. of 125 lamps is .23 ohm with a fall of 55 Volts.

On the armature of .00852 ohm the fall will be

$\frac{.00852}{.23} \times 55 = 2.04$ Volts.

Total foot-lbs. lost on armature face $= \frac{2.04^2 \times 44.3}{.00852}$

$= 21613$ ft. lbs.



Radiating surface
= 750 sq. in.

$\frac{21613}{750} =$ 29 ft. lb.

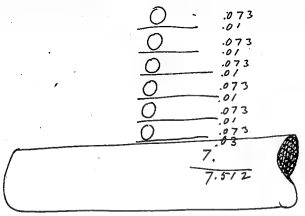
With 100 lamps this
would be reduced $\frac{1}{5}$
or slightly more than
23 ft. lb. per sq. in.
which agrees with that
for the common medicine
machine, See page 147.

So only a product of 6100 of current by turns is required by using the same core as with dynamo D and the same number of turns and layers.

The field is increased in length from 9 1/4 to 14 1/2 and the core should be increased in like proportion

$$\frac{6^2 \times 36 \times 14.5}{9.25} = 2032$$

If 7" drum length $\frac{2032}{7^2} = 42$" effective length and 1" for fibre washers $= 43$" total length



Mean diameter 7.512

Circumference 23.6.

573 turns to a layer

Total 6876 turns, abundance in excess.

Total length = 135-22.8 feet.

Resistance $= \frac{10.64 \times 13522.8}{58^2}$

$= 42.8$ ohms.

If we suppose the E.M.F.

13522.5
.010183
40568 4
10818 27
1352 25
135225
137.7

to be only the same the
Current will be one weber
and product by turns will
be 6876 which is
ample as only
6100 was required.

Weight = 13522.5 X .010183 = 137.7 lbs.
of copper in Magnets.

Shaft: 2 1/4" steel.

With 200 light dynamo, the capacity should be at least 250 lights.

With 250 lights from page 169 the ratio of increase of rods should be

$\sqrt{83} : \sqrt{250}$

$9.11 : 15.8$

$1 : 1.75$

The rods for 50 lights are

.192
N
.183

and depth should increase to .35

Increase armature in same proportion

9.7×1.75

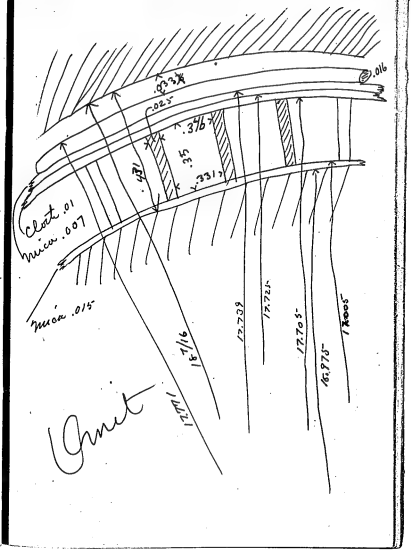
$= 16.975$" diam.

$1200 \div 1.75$

$= 700$ revolutions.

At 700 revs. the cutting speed is $\frac{700 \times 16.975 \times 3.1416}{12}$

$= 3111$ ft. per min.


.016
.376
.331
.35
.021
Clear .01
Mica .007
Mica .015
16 7/16
12.709
12.705
12.695
12.685
12.681

With a space equal to .431" the value of 1 Ct cutting at a speed of 1000 feet per m. is

= .223 Volts.

and product of turns by current = 5900

Allow for a total fall of 65 Volts.

The length of conductor is $\frac{65}{3.111 \times .223}$

= 94 feet

Which will be made 100 feet. or 1200 inches

$\frac{1200}{75}$ = 16 inches for cutting length of armature

May 14, 1881.

With plates $\frac{42}{1000}$ thick and paper insulation of $\frac{16}{1000}$ with 75 plates the thickness will be 4.275" and the total length of ends will average 16 + 4.5 = 20.5"

The resistance of the armature face or more up of these rods is

$$= \frac{75 \times \frac{20.5}{+339} \times 8.357}{12 \times 2 \times \left(\frac{.346 + .831}{2}\right)35 \times 1000000}$$

$$= \frac{1254.88875}{2543400}$$

$$= .004952$$

With 250 B.16 lamps
the external resistance
is $\frac{115}{4 \times 250}$

$= .115$ ohms.

With 55 volts fall on
.115 ohms there will
be within the armature
a fall of $\frac{.0045 \times 55}{.115}$ volts

$= 2.152$ volts.

The energy developed on
the face of the armature
is in the form of heat
is $\frac{2.152^2 \times 443}{.0045} = 45580$ ft-lbs.
per minute.

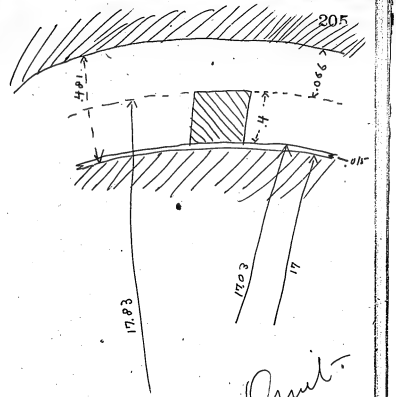
The radiating surface

b' $3.1416 \times 17.7 \times 20.5$

$= 1141$ sq. in.

which gives 40 ft. lbs. per sq. in. which is too great.

If we make the ratio of change of rods in similar dynamos as 1 to 2 instead of 1 to 1.75 the depth becomes 4 and assume diameter as 17. Then the following diagram


1.46
1.056
1.4
0.15
17.83
1703
17

Space .52
1" at 1000 ft = .2125

Space .275
1" at 1000 ft = .24

.52 − .275 = .245

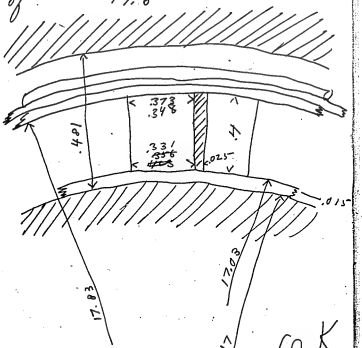
.24 − .2125 = .0275

.481 − .275 = .206

.245 ÷ .206 ÷ .0275 ÷
= .0231

The value for a space of .481"
1" at 1000 ft = .2169
at 700 revs. per min. this requires 90 ft. cutting and 9.7 at 700 feet. If we assume 100 ft. in 1200 inches it will require 16" length

of armature and add 10 % excess we have a length of 17.6"



Plates $\frac{42}{1000}$" thick
Paper insulation $\frac{15}{1000}$"
75 discs

O.K

The cross section is .1458 sq. in.
and total length of rods 22.2 inches

$$\text{Resis} = \frac{75 \times 22.2 \times 8.35 - 7}{12 \times 2 \times 145.800}$$

$$= .004 \text{ ohms.}$$

The face of E. M. F. in face of armature is 1.91 volts
and energy

$$\frac{1.91^2 \times 44.3}{.004} = 40402 \text{ ft-lbs.}$$

Radiating surface

$$= 3.1416 \times 17 \times 22.2$$

$$= 1186 \text{ sq. in.}$$

Heat radiated from surface of 1 sq. in. = 34 ft-lbs.

With 250 lamps are required (6 hr H.P.)
42 H.P.

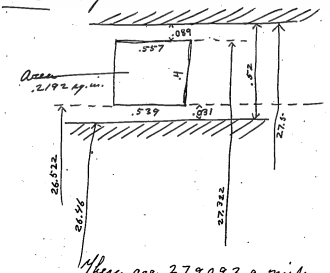
Suppose 250 H. P.
or 1 H. P. per lamp

700 | 250
2.06 | .3543
172

3" shaft of steel.

Make it 3 1/4"

C dynamo.



There are 279093 c. mils
in the above conductor
= 15.6 Ns. 10 B.W.G. wires.

$$R = \frac{10.33 \times 42.7 \times 73}{12 \times 279093}$$

= .00961 divide by 2

= .0048 ohms = the
resistance of entire rods
there being 146 each 42.7" long
and 73 commutators.

Clarke July 18, 1881.

The copper discs are of following dimensions

.065" thick

The area is 546.35 − 135.3

= 411.05

and multiply by thickness

= 411.05 × .065

= 26.71825 cu. inches.

Let us suppose as a most unfavorable condition that the entire amount is concentrated on the outside circumference and since the current passes from A to B two ways that the plates is folded in itself.

Half the circumference = 41.43"

and area of copper rod of this length is 26.71825 ÷ 41.43

= .6449 sq. in.

Clarke, July 18, 1881.

The circular mils =

.6449 ÷ .0000007854

= 821110

Resis. of 73 of these is

$$R = \frac{10.33 \times 41.43 \times 73}{12 \times 821110}$$

R = .00311

and ÷ 2 = .001555 ohms.

This must be added to the resis. of 73 rods =

.00961 + .00311

= .01272 ~~and ÷ 2 = 0~~ and if (as is the case) multiple arced with another

R = .00636

This is the most unfavorable showing possible for the discs of copper.

The diam. assume as 26.5"
The circumference will be
6.934 feet and travel at
350 revs. per minute is
2427 feet.
The strain on circumference
for 150 H.P. is 2040 lbs.
Divide this between 176 bars
= 11.2 lbs. per bar, or
5.6 lbs. on each leg.

Each bar is 42.7" long
and cross-section of .279093 sq. inch
Weight = $\frac{42.7}{12} \times .279093 \times .0000003027$
= 3 lbs.

Centrifugal force
$$= \frac{3 \times \left(\frac{2427}{60}\right)^2}{\frac{26.5}{24.2} \times 32.2}$$
= 138 lbs.

If supported by a
strap in the centre
the centrifugal force
of half a bar will
be 69 lbs.
Which puts a strain of
34.5 lbs. on
the lug.

Resistance coils for external circuit of dynamo C.
The work required will be 150 H.P. = 4950000 ft. lbs.

$$\frac{110^2 \times 44.3}{R} = 4950000$$

$R = .108$ ohm.

$4950000 \div 772$
$= 6412$ units of heat.

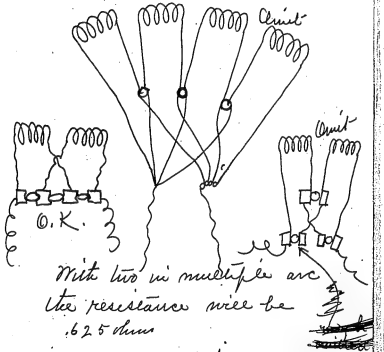
If water goes in at 60° and out at 120° each pound of water takes 60 units per minute and for 6412 units it takes 107 lbs. of water per minute = $107 \div 8.3$
= 13 gallons.

With 1300 feet of No. 15 B.W.G. = $\frac{72}{1000}$" in each barrel the resistance will be
Weight .0157 lbs. per foot.

$R = \frac{10.64 \times 1300}{5784}$

$R = 2.67$ ohms

which will be made about
to give 2.5 ohms.



With two in multiple are
the resistance will be
.625 ohms

$.625 \div .105 = 6$ barrels are
required.

A No. 10 B.W.G. wire has
area section of .0141 sq. in.
and two of the armature rods

.527
.539
0.4

.4384 sq. in.

= 31 No. 10 wire.

18 wires will be sufficient-
and 6 barrels being required
3 strands to each barrel.

May 18. 1881.

From page 275 the weight of the copper rods is 435 lbs. and radius 13.46" = 1.122 feet

The value for centrifugal force is $C' = \frac{4\pi^2}{g} . w . r . n^2$.

$\log 4 = 0.602060$

$(3.1412)^2 = .994302 = (0.497151)^2$

$w = 2.638459$

$r = 0.049993$

$(2.83)^2 = 1.531338 = (0.765669)^2$

$(32)^2$

$5.811.162$

$g = 32.167 = 1.507410$

4.308772

~~7858000~~

20360.

The aggregate pull is 20360 lbs. and half is 10180 lbs. but the pressure is on the

circumference and should be changed to diameter

Ratio

3.1416 : 1 :: 20360 :

= 6480 lbs.

and $\frac{1}{2}$ = 3240 lbs. is the bursting strain on the bands.

Heat developed in dynamo C.

Length of rods 42.7"

Cross section

$\left(\frac{.557+.539}{2}\right).4 = .2192$ sq. in

$= 219200$ sq. mils.

Resis in 73 rods

$= \frac{8.357 \times 73 \times 42.7}{12 \times 219200}$

$= .00994$ ohms

and true resistance of armature face for an equal number in multiple arc

$= .00497$ ohms

With 1000 lamps (A.16) the joint external resistance ought be .115 ohms.

and with 110 volts external the external horse-power

developed will be

$\frac{110^2}{.115} \times 44.3 = 4661139$ ft. lb.

$= 141$ H.P.

The fall of E.M.F. within the armature will be

$\frac{.00497}{.115} \times 110 = 4.754$ volts

The loss of energy on face of armature will be

$\frac{4.754^2 \times 44.3}{.00497} = 201442$ ft. lb.

$= 6.1$ H.P.

No. sq. in. on radiating cyl. face $= 27.3 \times 3.1416 \times 42.7$

$= 3662$ sq. in.

An amount of heat radiated per sq. inch

$= \frac{201442}{3662} = 55$ ft. lbs.

772

May 3, 1881.

Armington and Sims Fly Wheel

Comparison of the energy with the energy of dynamo.

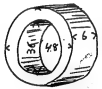
Since in the two cases the angular velocity is the same, in the formula for living force

$$L = \Sigma(mr^2)\theta^2$$

The angular velocity θ may be omitted and the comparison is simply one of inertia moments

$$\Sigma(mr^2)$$

The fly wheel is of the following dimensions



The moment of inertia is 273

$$K = M\,\frac{r'^2 + r^2}{2}$$

$$r^2 = \frac{\overline{36}^2}{18}. \qquad r'^2 = \frac{\overline{48}^2}{24}.$$

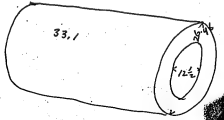
$$M = \frac{(1809.6 - 1017.9) \times 6 \times 450}{1728}$$

$$M = 1237 \text{ lb.}$$

$$K = 1237 \times \frac{450}{1800}$$

$$K = \frac{222\,6600}{5566.50}$$

In the armature we have six iron plates and three plates the equivalent of a wrought iron cylinder of the following dimensions



$$M = \frac{(551.5 - 122.72) \times 33.1 \times 48^2}{1728}$$

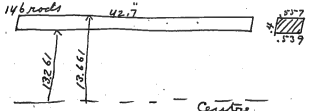
$M = 3984$ lbs.

$\bar{r}^2 = \frac{26.46^2}{13.23}$ $\quad r^2 = \frac{12.75^2}{6.25}$

$K = 3984 \times \frac{107.0475}{426.77}$

$K = \frac{+705.999}{426477.25}$

The copper rods form a cylinder of the following size for rods



$$M = \frac{.557 + .539}{2} \times 4 \times 42.7 \times 146 \times 55.0 \div 1728$$

$= 435$ lbs. $\quad \bar{r}^2 = 13.66^2 \Big/ \bar{r}^2 = 13.26$

$K = 435 \times 181.2$

$K = 78822$

There are 146 copper discs $\frac{65}{1000}$" thick and following dimensions

$$M = \frac{(543.25 - 135.3) \times 965 \times 146 \times 5.50}{1728}$$

$M = 1231$ lbs.

$\bar{r}^{1/2} = \overline{18,162.5}$ $\quad \bar{x} = \overline{6.56}$

$K = 1231 \times 108$

$K = 132948$

The $\Sigma(K) = 426777 + 78522 + 132948$

$\Sigma(K) = 638247$

[ITEM FOUND IN BOOK]

42.7 length of bars.
33.75 Useful length.

33.75) 8.95) 33.75 (37.7 %
26.85
6900
6265
6350

26.5 %

Ratio of useless to useful length of bar.

Resis. of 42.7" = .0048 ohms.

Resis of 11¼" = .001265 ohms

Measured total resistance was .0085 ohms

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Total Resis. with additional length of bars of 33⅓ % on face = .009765 ohms.

Gain in E.M.F. of 33⅓ %

Additional resis. of 14.9%

With .15 ohms external resis. the E.M.F. was 85 volts
With internal resis. of .0085 this gives a drop in the machine of 4.82 Volts.

If total is 85+4.82
= 89.82 volts
and we increase it 1/3
Total E.M.F. = 119.76 volts

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With external resistance of .15 ohms and internal resistance of .009765 ohms the drop in armature will be 7.7963 ohms.

External E.M.F.
= 111.9637 ohms.

The new length of bars is 53.95".
Available length is 45"
Ratio of useless to useful
19.9 %.

[ITEM FOUND IN BOOK]

3

With 4 calorimeters the resis. external is .15 and with five calorimeters will be .12 ohms.

With .12 ohms external resis. the E.M.F. was 85 volts.

With internal resis. of .0085 this gives a drop in the machine of 6.02

If total is 85 + 6.02

= 91.02 ohms.

and increase it - 1/3

Total E.M.F.

= 120.36

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4

With external resistance of .12 ohms and internal resistance of .009765 ohms the drop in armature will be 9.~~876~~ 14

External E.M.F.

112.~~484~~ 22

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[ITEM FOUND IN BOOK]

The resis. of armature was measured at- 82°F. & be .0085-

The end discs of copper will not be considered as rising in temperature.

The resis. of bars at- 60°F. is calculated to be .0048 ohms.

At- 82° F. it will be .0048 × 1.0472

= .005027 ohms.

The measured resis., being .0085 the resis. due to copper discs and connections is .003473 ohms.

If the temp. be increased in the rods to 130° the resis. will be .0048 × $\frac{.065 \times 70}{30} + 1$

= .00553 ohms.

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Total internal resis. will be

= .009 ohms.

With addition of ⅓ to the available lengths of bars. the resis. of bars at- 60°F. is .0048 + .0048/3

= .006065 ohms.

The resis. at- 130°

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.006065 × 1.15-17

= .006985 ohms.

Total resistance

.006985 + .003473

= .01046 ohms.

With total E.M.F.

= 121.36

The internal drop of E.M.F.

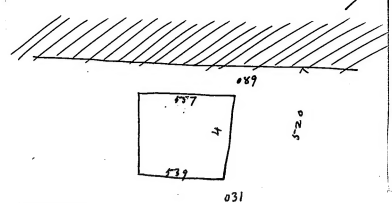
" = 9.76

Total Efficiency

= 111.6

7

[ITEM FOUND IN BOOK]



Cross-Section of bars of dynamo C as at present.

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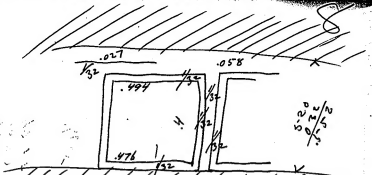
Cross-section .2192 sq. in.

If Relate 1/32" off each side = .0625 the

Cross-section = .1942

Which shows an increase of resis. in armature face of 13%.

8



From page 6 the resistance of the bars at 60°F is .006065 and this will be increased by 130°F

= .00685

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And at 130° F =

.00685 × 1.1517

= .00789 ohm.

Total =

.00789 + .003473

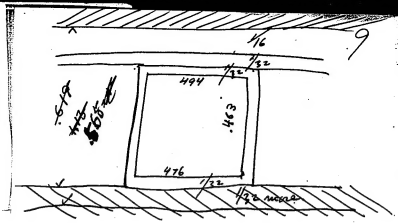
= .011363 ohms.

With total E.M.F. = 121.36

Internal drop. 10.5 volts

Extreme 110.86

[ITEM FOUND IN BOOK]



If 1/16 is added to the depth the cross section is .2245 sq. in. which is a decrease of resis. of 2 1/2 %.

.619
.03125
.65025
.52
1.13

1/32

3/32

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[ITEM FOUND IN BOOK]

.15 ohms for 4 barrels
4
.60 ohms for 1 barrel.

130 Volts total

.009765
130

.609765) 1.2694500 (2.1 ohms.
1219530 ×
499200 1 barrel.

.309765) 1.2694500 (4.1 ohm
1239060
303900 2 barrels.

.209765) 1.2694500 (6.05 ohms
1258590 ×
1086000 3 barrels.

.159765) 1.2694500 (7.9 ohms
1118355 ×
1510950 4 barrels.

.129765) 1.2694500 (9.8 ohm.
1167885 ×
1015650 5 barrel.

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130
2.1
127.9 ohms 1 barrel

130
4.1
125.9 ohms 2 barrels

130
6.05
123.95 ohms 3 barrels.

130
7.9
122.1 ohms. 4 barrels.

130
9.8
120.2 ohms 5 barrels.

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127.9 2
125.9 1.95
123.95 1.85
122.1 1.9
120.2

130 11 98.4% 3.9
119 11 94.5 7.4
108 11 87.1 9.4
95 12 77.7 7.0
85 10 70.7

127.9
125.9
123.95
122.1
120.2

[ITEM FOUND IN BOOK]

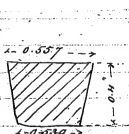
130) 127.9 (984
1170
1080
1040
800

125.9) 119.00 (94.5
1131
5690
5086
6540

123.95) 105.000 (87.1
99160
84400
84765
1635 0

122.1) 95.000 (77.7
85427
9530

120.2) 85.000 (70.7
84114
8600



73 rods 42.660 long.
72 rods 42.745 long.
1 rod 36.52 long.

Armature Rods of Dynamo C.

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